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CONTRIBUTIONS

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OF

THE STATE UNIVERSITY OF IOWA

VOLUME I NO. 1

1. On the influence of electrical discharge upon the acetylene flame — C. F. LORENZ
2. Standard cells — K. E. GUTHE AND C. L. VON ENDE
   (Reprinted from PHYSICAL REVIEW, Vol. XXIV., No. 3.)
3. Evaporation upon the Iowa River — A. G. SMITH

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ON EFFECTS OF THE ELECTRICAL DISCHARGE ON THE ACETYLENE FLAME.

By C. F. Lorenz.

HAVING had occasion some time ago to send through a cylindrical flame of illuminating gas the discharge from an induction coil, the primary of which was fed with alternating current, my attention was attracted to a slight increase in the brightness and whiteness of the flame — something that is doubtless a matter of common observation. It was easy to make adjustments so that the change became quite marked, and on repeating the experiment with acetylene the effect was much greater, so that it seemed worth while to try to find the most favorable conditions.

In addition to the change in the light it was noticed, that a surprisingly large amount of soot is deposited on the electrodes. If the burner is of metal and forms one electrode while the other is a wire held at the tip of the flame a bridge of soot rapidly forms between them and stops the discharge. The deposit of soot is mentioned by Semenov [1] in his account of experiments on sending a spark through flames of illuminating gas. He used Bunsen flames, and states that the discharge passes by way of the exterior non-luminous mantle, which becomes luminous with a purple light similar to that of a Geissler tube with low vacuum. In the present experiments a luminous, *i. e.*, carbon-containing flame was used, the luminous effect due to the carbon far overbalancing that of the outer mantle. It was found that the soot could be avoided perfectly by simply keeping the electrodes out of contact with the luminous part of the flame, and having them touch only the invisible envelope. Since this involves some non-axial disposition of the electrodes there is, of course, a tendency for the discharge to become unsymmetrical, but by placing them as shown in the photographs, one electrode near the base and the other near the middle or upper part of the flame, on the opposite side, a discharge that is very nearly symmetrical is obtained, provided the jet issues at considerable pressure from a small hole. There is no

[1] J. Semenov, Comptes Rendus, Vol. 134, p. 1199, May 26, 1902.

advantage in replacing the points by rings surrounding the flames, since in this case the discharge takes place from a point on the ring. The discharge may, however, be divided between two or more electrodes at either end by providing each with a separate steadying resistance (or inductance in case of alternating current). The simpler arrangement of one-point electrodes at the base and the middle of the flame was used in all the experiments described in the present note, which are preliminary experiments intended to bring out the more obvious characteristics of the phenomenon. The electrodes were brass wires 3 mm. in diameter, filed to a blunt point. The gas used was unpurified acetylene.

As shown by the pair of photographs *a* and *b* (Fig. 1) the discharge is accompanied by a shortening of the flame; *a* shows the unaffected flame and *b* the same while carrying a 60-cycle alternating current of several centi-amperes, the candle-power being about five times as great as without the discharge. The pair of photographs *c* and *d* are intended to show the effect of pushing up the current to a value great enough to cause metallic arcing; *c* was taken while the current was the least that would give the highest candle-power, and *d*, which shows the arcing at the electrodes, was taken while the current was about twice as great, the candle-power remaining practically unchanged. By observing the flame in a rotating mirror it is seen that it shortens and brightens each time the discharge passes. This appearance is shown in the photographs *e*, *f*, and *g*, which were made by moving the sensitive plate rapidly sidewise during the exposure; *f* was taken while the current was great enough to give the highest candle-power, and *e* while it was somewhat less. The photographs indicate that a higher temperature is reached by and near an electrode when it has one sign than when it has the other. The flame, of course, emits a humming sound.

The curves show the results of an experiment made under the following conditions: Height of flame 59 mm., distance (vertical) between electrodes 24 mm., lower electrode 3 mm. above the top of the burner, rate of flow of gas .34 cu. ft. per hour.

The candle-powers were obtained by comparison with a standardized incandescent lamp by a Bunsen disc photometer; the cur-

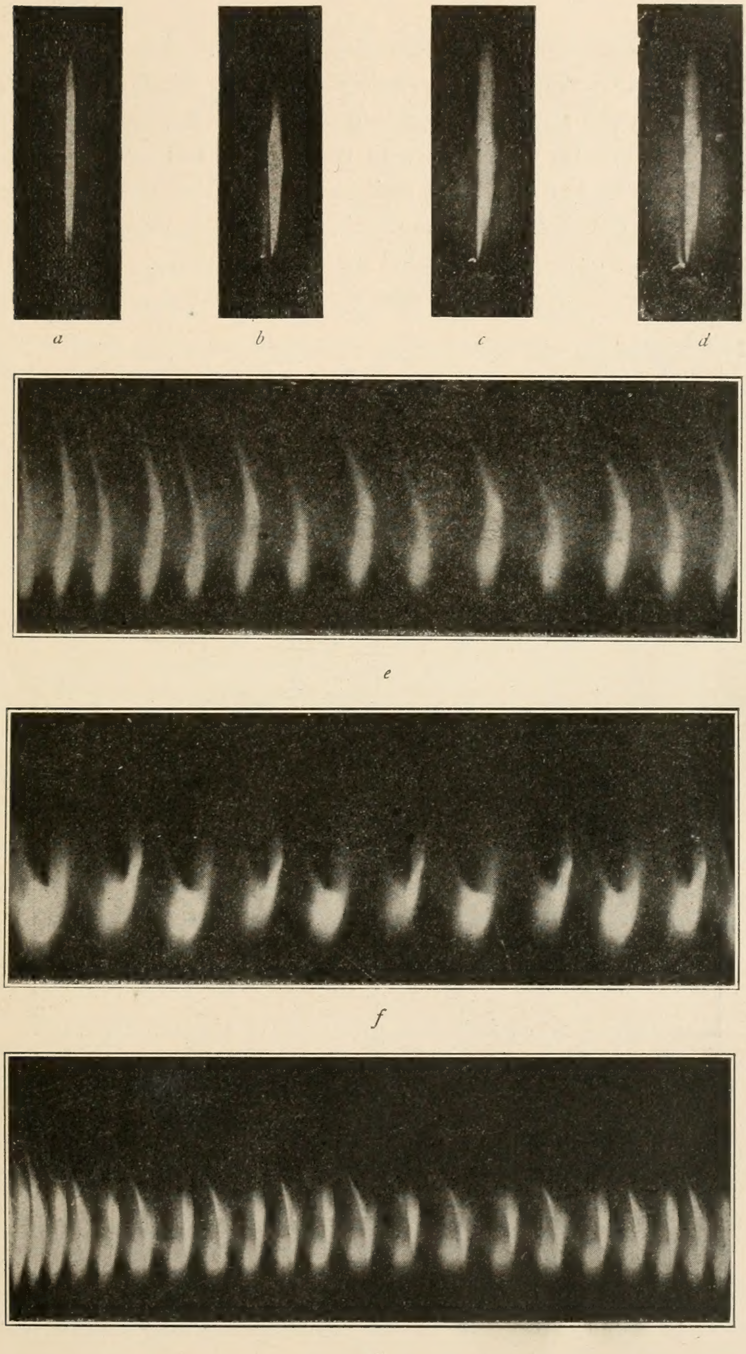

Fig. 1.

rents were measured by the expansion of a wire. The current was supplied by two transformers having long wire windings in series so as to step the 100-volt supply up to 4,000 volts, and was regulated by a rheostat in series with the (paralleled) primaries, this rheostat serving as a steadying resistance. The difference of potential between the electrodes was obtained by multiplying by 40 the readings of a voltmeter in parallel with the primaries.

From curve *I*, Fig. 2, it is seen that the candle-power increased

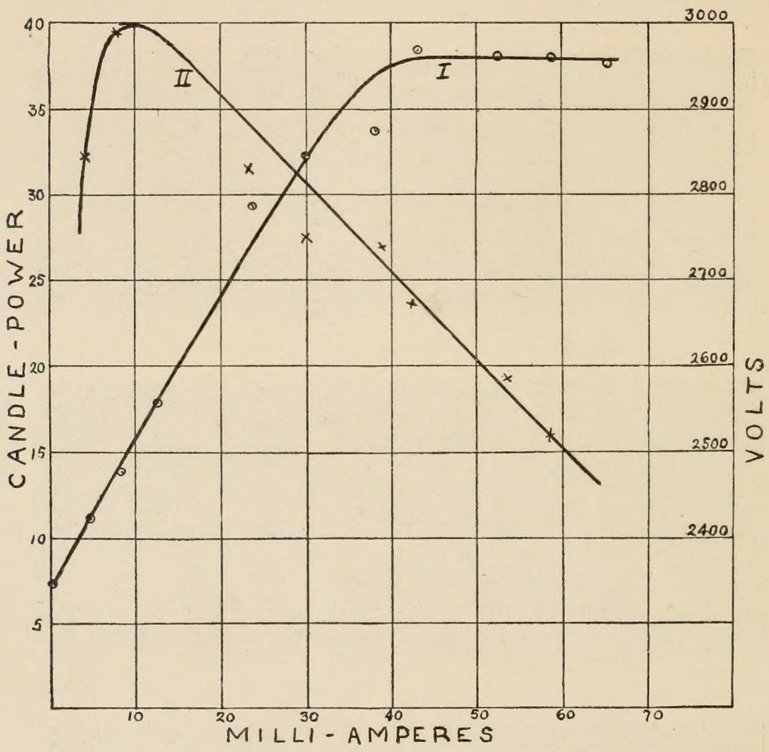

Fig. 2.

from 7.5 up to a limiting value of 38.0. This gain in (horizontal) candle-power of 31.5 is obtained by the expenditure at the flame of 122 watts, or about 4 watts per candle. As shown by curve 2, the difference of potential first increases with increase of current, as in the case of an ordinary resistance, and then decreases, as in the case of an arc, but the bend in the curve occurs long before there is an appreciable racing at the electrodes.

The effect of a direct current on the flame was also tried. The source consisted of several small direct-current machines having their armature in series and giving a total of about 2,500 volts. An almost noiseless, steady light resulted, but the experiments had to be discontinued before any measurements were made.

Such a current-carrying acetylene flame constitutes a convenient source of white light, strong in the violet end of the spectrum, and several other more or less useful applications suggest themselves. When direct current is used it may be applied in the several cases [1] in which it is desired to produce rapid variation in the intensity of a light by small currents, such as microphone currents, or currents interrupted by a tuning fork; the secondary of an induction coil, which serves at the same time as a steadying resistance, is put in series with the flame and the variations or interruptions are made in the primary. Similar rapid variations in the light can also be obtained by the use of a Koenig manometric capsule, as with an ordinary flame. As a telephone receiver the flame works well; the arrangement is obviously distinct from that of Ruhmer[2] as well as from that of Gabritschewski and Batschinski,[3] and is more like the speaking arc of Simon.[4] Even with a small flame conversation could be understood at a distance from the flame, and had a clear, natural ring. An effective telephone transmitter was obtained by feeding the flame through a manometric capsule, the words being spoken into the latter; the receiver was connected to the short wire winding of an induction-coil having its long wire winding in series with the flame; it was necessary to cut out the roar in the receiver due to the fluctuations of the dynamo current by the use of a condenser and choking-coil.[5]

I desire also here to express my best thanks to Professor K. E. Guthe for the very kind encouraging interest that he has taken in these experiments from the beginning.

September, 1906.

[1] See for example, E. Ruhmer, Kinetomagraphische Flammenbogenaufnahmen u. das Photographophon, Ann. der Physik., Vol. 5, p. 803, 1901.

[2] E. Ruhmer, Physikalische Zeitschrift, Vol. 2, p. 325, 1901.

[3] Gabritschewski and Batschinski, Ann. der Physik., Vol. 11, p. 223, 1903.

[4] Simon, Wied. Ann., Vol. 64, p. 233, 1898.

[5] W. Duddell, Electrician, Vol. 46, p. 269, Dec. 14, 1900, and Simon, Physikalische Zeitschrift, Vol. 2, p. 258, Jan., 1901.

STANDARD CELLS.

By K. E. Guthe and C. L. von Ende.

1. According to recent investigations electrolytically prepared mercurous sulfate seems to be superior to chemically prepared sulfate as the depolarizer in standard cells[1] and the first results of a series of observations on cadmium cells[2] containing this substance showed for a period covering several months a remarkable agreement of their electromotive forces. For this reason one of the authors made use of Clark and cadmium cells with electrolytic mercurous sulfate for the determination of the electromotive forces of standard cells by absolute measurement.[3]

These cells have been transported from Washington to Iowa City, being carefully protected against mechanical disturbances. During the past winter they stood, however, for some weeks in diffused light and were exposed for a few days to large temperature variations. A comparison of the cells after this time showed that the electromotive force of the cadmium cells had decreased relatively with respect to that of the Clark cells, but accurate measurements could not be made at that time on account of lack of sufficiently sensitive instruments. The comparisons reported on in this paper were made with a calibrated Wolff potentiometer and a galvanometer allowing with certainty a reading to the fifth decimal place.

The cells were placed in a thermostat whose temperature could be kept constant at 25° C. within 0.02 degree. The temperature was measured by means of a thermometer subdivided into fiftieths of a degree and calibrated at the Bureau of Standards. Table I. shows the relative change of the electromotive forces of the cells in the interval of a year. The R series are Clark cells with electrolytic

[1] Wolff, Trans. Amer. Electroch. Soc., vol. 5, 49, 1904. Carhart and Hulett, ibid., vol. 5, 59, 1904. Hulett, Zeitschr. f. physik. Chem., vol. 49, 483, 1904; Phys. Rev., vol. 22, 321, 1906. Compare also: Reichsanstalt, Zeitschr. f. Instr. kunde, vol. 26, 120, 1906.

[2] Carhart, Trans. Internat. Electr. Congr. St. Louis, vol. 2, 125, 1904.

[3] Guthe, Bull. Bur. Standards, vol. 2, 33, 1906.

mercurous sulfate, C_3 and K_{10} cadmium cells with chemically prepared sulfate and the rest cadmium cells with the electrolytic material. More detailed information as to the construction of these cells may be found in the Bulletin of the Bureau of Standards, vol. 2, p. 60. Some of the cells have been set up by Professor Carhart, some by Professor Hulett. As reference value in the following table the electromotive force of the Clark cell as determined by absolute measurement was chosen, namely, 1.42040 volts at 25° C.

Table I.

Old Cells.

	Date of Construction.	September 17, 1905.	October 15, 1906.	November 28, 1906.	January 12, 1907.
R_2	May 1904.	1.42040	1.42040	1.42040	1.42040
R_4		40	40	40	41
C_3	Nov. 1903.	1.01857	1.01842	1.01844	1.01842
E_2	Jan. 1904.	31	04	01	1789
F_8	Feb. 1904.	27	19	22	1822
F_9		28	08	07	1799
K_6	July 1904.	33	24	25	1826
K_{10}		33	11	12	02
O_1	Feb 1905.	33	23	23	24
O_2		33	19	22	21

The change in most of the cadmium cells amounts to about 0.0001 volt. Since the potentiometer was carefully calibrated and the thermometer correction known, this change is larger than the possible error in the apparatus. The relative values of F_8, K_6 O_1 and O_2 have remained about the same as last year, but for the others the decrease has been larger and quite irregular.

2. To decide the question if a change had taken place in the Clark cells chosen as reference standards it became necessary to construct new standard cells. At the same time we wished to ascertain how closely such cells would agree in electromotive force if constructed by different observers and with material from different sources. No such comparative investigation has yet been published so far as we know.

Professor Hulett kindly sent us some of his electrolytic mercurous sulphate and we prepared two different lots following closely the method published by him. We shall designate these two as lot 1

and 2 respectively. The sulfate was made from pure mercury in an acid prepared by mixing one part of concentrated sulfuric acid of specific gravity 1.84 with six times its volume of distilled water. The current density was between two and three amperes per 100 square centimeters. The first lot consisted of very fine crystals; the second was stirred longer after the breaking of the current and was therefore coarser.

The sulfate was filtered in a Gooch crucible and after the acid had been thoroughly drained off was washed repeatedly with alcohol and saturated zinc or cadmium sulfate solution. We found it necessary to be very careful in washing, especially with the finest crystals. After the last washing with the salt solution the top layer was removed and the paste prepared in the usual manner.

The mercury was either distilled by Hulett's method[1] or distilled twice in vacuo in an ordinary mercury still.

The zinc amalgam was prepared in the usual way by dissolving zinc in mercury. In some of the cadmium cells we used an amalgam prepared electrolytically.

Clark Cells.

3. Two series were set up, the *a* and *b* series. In the *a* series the zink amalgam contained 9 per cent. of zinc. Our mercurous sulfate No. 1 was used in the *a* series. In the *b* series the amalgam contained 10 per cent. of zinc, and Hulett's mercurous sulfate was used. Mercury distilled by Hulett's method was used in cells a_1, a_2, b_1 and b_2, the other mercury in a_3 and b_3. The zinc sulfate crystals were recrystallized from a neutralized solution of Schuchardt's c. p. sulfate and the solution in the cells made from these crystals.

In Table II, the electromotive forces as determined on different days are tabulated. The values for the cells with the very fine mercurous sulfate were at first somewhat low, but increased rather suddenly between the ninth and fourteenth day, then slower until they reached a value a little higher, but still agreeing well with that of the old Clark cells. The b cells, the mercurous sulfate of which had not been as difficult to wash, had immediately after construction a value agreeing within 0.00003 volt with that of the old cells and remained constant ever since.

[1] Hulett and Minchin, Phys. Rev., vol. 21, 388, 1905.

The great difference in the size of the mercurous sulfate crystals had apparently no great influence upon the final value of the electromotive force ; the two different samples of mercury behaved electrolytically exactly alike.

TABLE II.

Clark Cells.

	Date of Construction.	Oct. 14, 1906.	Oct. 20, 1906.	Oct. 26, 1906.	Nov. 6, 1906.	Nov. 20, 1906.
a_1		1.42025	1.42029	1.42037	1.42041	1.42043
a_2	Oct. 13, 1906	—	-	—	40	43
a_3		24	30	38	42	43
b_1			38	39	38	38
b_2	Oct. 19, 1906		37	40	39	38
b_3			37	39	38	38

	Date of Construction.	Dec. 5, 1906.	Dec. 24, 1906.	Jan. 19, 1907.
a_1		1.42044	1.42045	1.42045
a_2	Oct. 13, 1906	44	45	45
a_3		45	44	45
b_1		38	38	--
b_2	Oct. 19, 1906	38	38	38
b_3		37	38	38

We also prepared some cells in which the directions were not followed very closely. In a_4, a_5, and a_6 the mercurous sulfate (Hulett's) was not thoroughly freed from alcohol which produced a lowering of the electromotive force by over 0.00040 volt without an appreciable change in course of time. Cells b_4 and b_5 were prepared with our mercurous sulfate No. 1, thoroughly washed, but it was mixed with about the same bulk of zinc sulfate crystals and the paste made very thin. These cells had from the start an electromotive force 0.00015 volt higher than the normal value and remained perfectly constant.

It is apparent that the treatment of the mercurous sulfate plays a much more important rôle than the sulfate in itself. a_1, a_2 and a_3 as well as b_4 and b_5 were made with our sulfate, but the former cells show quite a different behavior from that of the latter ; the same is true of the cells in which Hulett's sulfate was used.

After a few weeks a_3, a_4 and a_5 as well as b_4 and b_5 were placed for three hours on a circuit of 1,000 ohms external resistance, Nov.

TABLE III.

Clark Cells.

	Date of Construction.	Oct. 14, 1906.	Oct. 18, 1906.	Oct. 20, 1906.	Oct. 26, 1906.	Nov. 6, 1906.
a_4		1.41968	1.41992	1.41992	1.41994	1.41982
a_5	Oct. 13, 1906	80	1.42004	1.42003	99	80
a_6		87	06	05	1.42005	93
b_4	Oct. 19, 1906			1.42056	1.42057	1.42056
b_5				56	57	56

	Date of Construction.	Nov. 23, 1906.	Dec. 5, 1906.	Dec. 24, 1906.	Jan. 19, 1907.
a_4		1.41980	1.41981	1.41980	1.41980
a_5	Oct. 13, 1906	80	81	81	80
a_6		91	91	91	91
b_4	Oct. 19, 1906	1.42053	1.42054	1.42055	1.42054
b_5		53	54	54	54

4 and Nov. 23 respectively. It was hoped that, if free acid had been present, this treatment would change the electromotive force. After opening the circuit the electromotive force had dropped about 0.00040 volt, but it returned in about two hours to about its original value and remained constant after that.

CADMIUM CELLS.

4. The cadmium sulfate crystals were obtained from three different solutions; of these *A* was made from Merck's pure cadmium sulfate, *B* from Baker's c. p. material, and *C* from mixed turbid crystal spicked out from either *A* or *B*. In the c series lot two of our electrolytic mercurous sulfate washed with alcohol and saturated cadmium sulfate solution (made from selected clear crystals) was used. The amalgam contained 12.5 per cent. cadmium and was made by dissolving Kahlbaum's cadmium (käufflich) in warm mercury.

Since it is rather troublesome to obtain a sufficient number of perfectly clear crystals from a small bulk of cadmium sulfate solution, we used also somewhat turbid crystals. The crystals in c_1 were selected large clear crystals from solution *C*, in c_2 small selected, somewhat turbid crystals from solution *B*, and in c_3 large selected crystals somewhat cloudy, from *A* and *C*.

In the d series Hulett's mercurous sulfate was used, treated the

same way as ours in the c series. In d_1 and d_2 selected clear crystals were used from solution *C*, in d_3 and d_4 small crystals which had been formed at the bottom of the crystallizing dish from solution *A* and which were washed a few times with distilled water, after the mother liquor had been filtered off. No attempt was made to select the crystals for these cells. The solution in the cells was always made from the crystals used in filling. d_1 and d_3 contain the same amalgam as the c cells, d_2 and d_4 electrolytically prepared amalgam.

Table IV. shows that the cadmium cells c gave at first a value for the electromotive force of nearly 1.01840 volt which dropped, however, within a few days by about 0.0001 volt and remained fairly

TABLE IV.

Cadmium Cells.

	Date of Construction.	Nov. 3, 1906.	Nov. 6, 1906.	Nov. 10, 1906.	Nov. 12, 1906.	Nov. 17, 1906.
c_1		1.01840	1.01838	1.01836	1.01835	1.01835
c_2	Nov. 2, 1906	38	36	35	34	35
c_3		39	37	36	33	33
d_1				1.01842	1.01840	1.01834
d_2	Nov. 9, 1906			42	42	37
d_3				46	40	28
d_4				47	45	35
	Date of Construction.	**Nov. 23, 1906.**	**Nov. 28, 1906.**	**Dec. 5, 1906.**	**Dec. 13, 1906.**	**Jan. 19, 1907.**
c_1		1.01834	1.01833	1.01831	1.01829	
c_2	Nov. 2, 1906	35	34	32	30	1.01829
c_3		32	32	31	28	28
d_1		1.01827	1.01823	1.01815	1.01811	1.01805
d_2	Nov. 9, 1906	33	31	24	19	13
d_3		19	14	10	06	03
d_4		24	19	11	07	02

constant after that. The drop in the d cells is, however, considerably larger than in the c cells, and especially pronounced in d_3 and d_4. The different methods of preparing the amalgam does not seem to have an effect upon the electromotive force.[1]

[1] Towards the end of December, 1906, we exchanged Clark cell b_1 and cadmium cell c_1 for a Clark and cadmium cell constructed by Dr. Wolff at the Bureau of Standards. Wolff's Clark cell has an electromotive force 0.00006 volt lower, and his cadmium cell an electromotive force 0.00003 volt. lower than ours of the same type. Dr. Wolff writes that he has found practically the same difference in his comparisons at the Bureau which shows that the cells have not been affected by transportation.

5. In a general way this investigation corroborates Hulett's recently published results,[1] that Clark cells containing electrolytic mercurous sulfate when set up with proper precautions will have an electromotive force of 1.42040 volts at 25° C. within a few one hundred-thousandths of a volt and remain constant in course of time. The cadmium cells show immediately after the setting up an electromotive force of 1.0184 volts, closely agreeing with the value given by Hulett.

There is, however, one notable difference. Hulett's *A* cells, set up October 21, 1905, have an electromotive force of 1.01843 volts and have kept this value for at least six months, later results not having been published. His old cells (*F* series) are now about 0.00011 volt lower. Hulett, therefore, drew the conclusion that in the course of time the electromotive force slowly decreases and described a number of very interesting experiments which seem to show that the system in the cathode leg of the cells is not in equilibrium. But the *F* cells, though originally of the same high value, decreased to their present low value within a week, and have remained, with one exception, constant since then. A similar rapid decrease is noticeable in the *J* and *K* cells on which Professor Carhart[2] has reported. Hulett explains this difference in behavior by a difference in the depth of the paste. We have made the paste in the cells over two centimeters deep, but nevertheless the initial decrease is rapid. This difference in the behavior of Hulett's and our cells can hardly be due to the mercurous sulfate and we are at a loss to explain it unless it is to be found in the unstable equilibrium between the cadmium sulfate solution and the rest of the material at the cathode or in a difference in the method of construction of which we are not aware. Our results do not extend over a sufficiently long period to decide the question whether or not there will be a continuous slow decrease of the electromotive force in course of time.

After the satisfactory results obtained with the Clark cells the apparent difficulty for different observers to set up cadmium cells, which remain constant from the start and are practically identical

[1] Hulett, Phys. Rev., vol. 23, 166, 1906.

[2] Carhart, l. c.

in their electrical behavior, seems to indicate that there is still some factor of uncertainty in the method of construction for the latter and this demands further investigation.

The large changes in the electromotive forces of the old cadmium cells mentioned above, are, possibly, not due to a continouus gradual decrease in course of time but to sudden changes brought about by the severe treatment to which they were subjected. It is however very gratifying to know that the causes for such changes have had no influence whatever upon the electromotive force of the Clark cells, since the latter agree so closely with the newly prepared cells.

Conclusions.

1. The electromotive forces of standard cells set up with electrolytic mercurous sulfate by different observers and from different sources agree under otherwise perfectly equal conditions within a few one hundred-thousandths of a volt.

2. Mercury twice distilled in an ordinary vacuum still gives the same results as mercury distilled by Hulett's method.

3. Amalgam prepared in the usual way gives the same results as electrolytic amalgam.

4. Clear and cloudy cadmium sulfate crystals produce no difference in the electromotive force of the cadmium cells.

5. Clark cells with electrolytic, coarsely grained mercurous sulfate have immediately after construction an electromotive force of 1.4204 volts at 25° C. within a few one hundred-thousandths of a volt and remain constant in course of time.

6. We have been unable to construct cadmium cells which do not show an initial decrease in electromotive force.

January, 1907.

EVAPORATION UPON THE IOWA RIVER.

By Arthur G. Smith.

THE following series of observations to determine the amount of daily evaporation from the surface of the Iowa River and also from a free water surface on land near the river were undertaken with the advice of Mr. A. H. Horton, Engineer in Hydrographic Branch of the United States Geological Survey. Through the kindness of Mr. Horton a river evaporation station was established at Iowa City and equipped with the proper apparatus for the work.

It was thought that interesting results could be obtained by the location not only of an evaporation pan which should be floated in the river but also one placed upon the land near the river, thus obtaining a comparative determination for the two locations.

The pans used were the regular United States evaporation pan, which is of heavy galvanized iron three feet square and eighteen inches deep. One of these pans, which will be designated as the river pan was floated upon the surface of the river by means of two galvanized iron pontoons; the upper edge of this pan being about three inches above the surface of the river. The readings upon the evaporation from this pan were from time to time destroyed by waves washing into the pan, but it was thought better to lose a few days' observations then to prevent free access of the wind and air to the pan by surrounding it with a floating guard against waves.

The second pan, which is termed the land pan, was sunk in the ground upon the bank of the river at an elevation of about seven feet above the river surface. It was open to the sun at all hours as freely as the river pan.

The station was upon the west side of the river upon a stretch of river extending nearly due north and south with a hill, sparsely covered with trees, rising gradually to the westward to a height of about seventy-five feet at a distance of three hundred and fifty feet from the river.

The pans were open freely to wind ranging from north through the east to south, while winds from westerly directions were more or less warded off by the hill and trees.

The pans were placed in position July 7 and readings continued until November 18, when the formation of ice, particularly upon the land pan, rendered the measurements of no value. In passing it may be noted that the low conductivity of water was well shown in the reading made November 19 upon the land pan ; when it was covered with ice an inch in thickness the water immediately under the ice showed a temperature of 33.5°.

The amount of daily evaporation was determined by the following method. In the center of each pan was erected a fine metal point and at each observation sufficient water was poured into the pan to just submerge this point. A cup being used which held just water enough to fill the pan .01 inch the number of cups necessary to fill the pan gave the evaporation in hundredths of an inch. In case of precipitation the precipitation as determined by ordinary rain gauge less the number of cups taken out of pan to bring the water down to metal point gave the amount of evaporation.

It was planned to read the pans twice daily but outside work prevented the readings being made regularly in the evening, and hence the values given in the accompaning tables are the readings made in the morning at eight, central time.

The mean daily temperatures are given as observed by the resident weather observer, Dr. Karl E. Guthe, who has kindly furnished them for completing these desirable data for evaporation observations.

The saturation deficit is computed and is defined as the difference between the vapor pressure actually present in the air and the vapor pressure that would be present were the air saturated at the observed temperature. If K represents the vapor pressure of saturation at the observed temperature and H be the relative humidity, then d, the saturation deficit is given by,

$$d = K(1 - H).$$

The saturation deficit is given here in the belief that it is more intimately connected with evaporation than is relative humidity. The value given in the series of observations is the mean of the sat-

uration deficit computed from two readings made daily at 7 A. M. and 7 P. M.

The relative humidity was determined by an ordinary sling psychrometer, readings being made twice daily and the mean taken, as in the case of the saturation deficit.

The desirability of wind and sunshine observations is self-evident. Evaporation is dependent upon so many factors that the brief series of observations here given can hardly be looked upon as more than the accumulation of a few data from which a few general conclusions may be drawn.

It is certainly worthy of note that the daily average evaporation for the river pan is in excess of that for the land. It may be urged that this is due to a more open exposure of this pan, but the writer believes it due rather to less friction on the part of surrounding water surface to movement of the air than of the ground surrounding the land pan. The temperature of the water in the river pan is found to be higher than that of the land pan by such amounts ranging from 0.9° to 3.8° for the month, and this also will explain a difference in the amount of evaporation.

The effect of running water and the formation of waves is shown in the higher temperatures of the water outside than the water inside of the river pan, — an average difference of almost one degree. While amounts of evaporation given are for the entire twenty-four hours, from one morning to the next, it is interesting to note that the average for thirty-one days, when readings were made both night and morning, gave the evaporation during the day, that is, from 8 A. M. to 7 P. M. as 8.03, while for the night, that is, from 7 P. M. to 8 A. M. the average is 7.74. This would indicate a relatively larger evaporation during the night than is popularly supposed. The small number of observations, however, may be responsible for an apparent equality affected by a few exceptionally large results, while a more extended series would show a greater difference.

The average temperatures for the months involved may be compared with the average for those months as shown by the Iowa weather service. These latter are the averages from forty five years of observations made at Iowa City. The mean temperatures are as follows for 1906 :

July	72.8
August	75.5
September	70.5
October	51.8
November	35.5

while the averages for the past forty five years are :

July	74.2
August	71.6
September	63.4
October	51.1
November	35.5

These data show that for July the temperature was below average and in August, September and November above average, so that, on the whole, we may conclude that in so far as the evaporation was dependent upon temperature it should be in excess of the average.

The precipitation data for this station show that the rain-fall for the season involved was below the average for past years, yet this would give no particular idea whether the evaporation should be in excess or less than for average years. No data upon the average number of rainy and foggy days during these months is available. The rainfall data for this station are as follows, as observed by Dr. Guthe, for the year 1906 :

	Inches.
July	1.42
August	5.34
September	0.89
October	1.48
November	3.08

while the averages of the past forty-five years are :

	Inches.
July	4.50
August	4.26
September	3.83
October	2.54
November	2.32

These data show that this portion of the year was below normal in the total amount of precipitation, which might indicate an evaporation in excess of the normal. When the saturation deficit given in ten-thousandths of an inch is arranged in the following classes the days showing the respective saturation deficit 0 to 500, 500 to 1000, 1000 to 1500, 1500 to 2000, and 2000 to 2500, the average daily

evaporation for these periods is found to be 7.5, 13.8, 14.7, 14.8 and 17 respectively.

The relation of relative humidity to evaporation may be shown as follows: grouping the respective humidites in series of four we find the average evaporation as follows: for humidity ranging between and including the numbers we find:

Relative Humidity.	Average Evaporation.
71–74	18.6
75–78	12.2
79–82	11.3
83–86	16.3
87–90	11.9
91–94	9.3
95–98	9.5

As was said earlier in the paper, the scantiness of the data allow only results to be stated and general conclusions to be drawn. The following pages give the observations from which the above results have been found.

In the following tables the precipitation and evaporation is given in hundredths of an inch. The state of weather is indicated as follows: 1 — clear; 2 — part cloudy; 3 — cloudy. The wind velocities as follows:

1. Light air. Just sensible, giving direction to smoke.
2. Gentle breeze. Setting in motion leaves of trees.
3. Moderate breeze. Swaying small twigs; starting dust.
4. Fresh breeze. Swaying small branches; blowing up dust.
5. Strong wind. Swaying large branches; blowing up twigs.
6. High wind. Blowing away all loose, unsecured material.
7. Gale. Damaging standing grain.

July.

	River Pan.											Land Pan.	
Date.	Mean Temperature.	Wind. Direction.	Wind. Velocity.	State of Weather.	Precipitation.	Relative Humidity.	Saturation Deficit.	Temperature of Water. Outside.	Temperature of Water. Inside.	Evaporation.		Temperature of Water.	Evaporation.
7	67.5		2	2	0	84	1088	74	74			74	14
8	67.5		2	1	0	82	1228	78.3	78	21		68.5	14
9	71.5		2	1	0	87	733	74	74	50		70	27
10	73.5		1	1	0	84	1122	76	75.5	39		72	23
11	69.5		a	1	0	87	1059	a	a	a		69	23
12	78		1	1	0	74	2024	a	a	a		74	17
13	81		1	3	Tr	93	469	a	a	a		77	12
14	77.5		1	1	0	97	246	a	a	a		76	12
15	78.5		2	3	0	82	1359	78.3	78	240		70	15
16	62.5		2	1	0	91	477	70.5	70	14		68	15
17	67.5		2	1	0	87	723	74	73	14		70	17
18	66.5		2	1	0	95	367	73	72.5	23		69	17
19	71.5		2	3	0	80	1580	75	74.6	13		73	19
20	74		3	1	0	75	1925	76.5	75	14		73	12
21	77	NW	1	1	0	90	737	78	77	17		76	19
22	74	a	a	1	0	86	1192	79	79	20		76.5	21
23	74	NW	6	1	0	72	846	77	75	14		71	27
24	68	NE	2	1	0	86	712	75.2	74	35		69	27
25	73	S	2	1	0	78	1348	72	71	23		75	27
26	74	NW	2	1	0	86	1072	75.5	75	b		72	19
27	73	SW	1	1	0	93	415	75	74	b		72.5	23
28	78	NE	1	1	0	84	1192	77	77	b		75	19
29	75	NW	3	2	12	90	1073	77	76	23		72.5	22
30	73.5	NW	2	1	0	86	850	75.7	75	31		72	21
31	69.5	NW	a	3	0	92	493	75.6	75	23		71.3	17
Total					12					614			462
Mean	72.6							75.8	74.9	29.2		72.2	18.5

a — no reading made. b — observation discarded.

August.

	Water Pan.										Land Pan.	
Date.	Mean Temperature.	Wind. Direction.	Wind. Velocity.	State of Weather.	Precipitation.	Relative Humidity.	Saturation Deficit.	Temperature of Water. Outside.	Temperature of Water. Inside.	Evaporation.	Temperature of Water.	Evaporation.
1	73	SW	2	3	23	87	911	a	a	a	70	2
2	78	SE	3	2	0	87	968	a	a	a	73	23
3	87.5	a	a	2	0	90	737	a	a	a	76	23
4	79.5	a	2	1	0	87	1028	81	81	47	77	9
5	80.5	SW	1	3	50	95	382	81	80	17	77	9
6	76.5	SW	3	3	2	97	261	80.5	80	17	76	14
7	78	SW	1	3	46	95	327	79	78	15	75	9
8	78	SE	2	3	10	87	1222	79	79	17	76	14
9	75.5	a	a	2	253	95	394	75.5	76	b	78	b
10	75	a	a	3	6	95	1355	76.3	76	15	74	19
11	76.5	a	1	1	0	82	1483	a	a	15	74	12
12	74.5	E	2	1	0	80	1542	78	77.5	19	73	19
13	72.5	SE	1	1	0	80	1426	77	76	19	71	18
14	73	S	2	1	0	87	823	77	77	25	72	14
15	74.5	SW	1	1	0	87	948	78	76.6	17	72	23
16	74.5	SE	2	1	3	84	1467	77	76	15	73	18
17	82.5	SW	1	3	40	92	685	79.7	78.5	18	77	15
18	80	a	a	3	0	92	767	80.5	80	15	76	11
19	77.5	SW	2	2	0	90	620	78.2	78	13	74	10
20	81.5	SW	3	1	0	87	1307	80.5	80	12	76	10
21	83.5	SW	2	1	0	87	1295	82.4	80	16	78	13
22	82	W	2	1	0	89	1303	83.5	82.5	17	79	25
23	70.5	SE	3	1	0	86	1668	83	82	17	79	14
24	83.5	NE	3	3	40	89	1049	82.5	81	b	78	18
25	76	a	a	2	3	92	704	81	80	17	76	20
26	75	NW	4	3	0	84	960	79.4	78	b	76	25
27	60.5	NW	3	1	0	83	1010	74	72	19	65	20
28	62.5	S	2	1	0	74	1803	70	69	23	65	20
29	67.5	W	4	1	0	83	1189	70.4	69.8	30	69	14
30	69.5	W	1	1	0	89	674	71.5	71	14	70	19
31	68	S	1	1	0	85	982	72.4	72	21	70	22
Total					476					470		488
Mean	75.5							78.3	77.3	16.2	73.7	16.3

a — no reading made. b — observation discarded.

September.

	River Pan.											Land Pan.	
	Date.	Mean Temperature.	Wind. Direction.	Wind. Velocity.	State of Weather.	Precipitation.	Relative Humidity.	Saturation Deficit.	Temperature of Water. Outside.	Temperature of Water. Inside.	Evaporation.	Temperature of Water.	Evaporation.
	1	69	SE	3	3	0	80	1839	72.3	72	15	69	11
	2	76	SE	2	1	13	93	455	72.5	72	14	70	7
	3	68.5	NE	4	1	13	84	1032	71	70.5	7	68	12
	4	68	NE	1	3	0	88	696	70	69	19	66	14
	5	62.5	SW	2	1	0	90	463	69.4	69	8	64	4
	6	68.5	S	1	1	0	90	686	70	69	16	66	19
	7	73.5	S	1	1	0	85	1267	71	71	14	69	14
	8	75.5	SW	2	1	0	88	1103	74	73.5	4	71	9
	9	78.5	S	3	1	0	86	1215	76	75	a	74	14
	10	81	SW	3	1	0	82	1600	77	76	18	73	15
	11	80	SE	1	1	0	90	756	79.2	78.6	18	78	6
	12	79	S	2	3	0	91	743	78	77	15	73	13
	13	67.5	NW	5	3	0	92	450	71.5	71	4	66	18
	14	61.5	E	5	1	5	82	1112	69	68	16	63	4
	15	65.5	SE	4	3	0	91	1188	67	67	23	66	19
	16	78	S	2	1	0	90	760	70	70.5	9	70	9
	17	81.5	NE	2	2	0	93	455	73.7	72.8	21	72	8
	18	77.5	NE	3	1	14	86	910	76	75.3	15	72	10
	19	80	N	2	2	0	89	867	76	75	15	74	24
	20	72.5	NW	2	1	0	a	a	74	73	6	68	0
	21	75	SE	3	1	0	89	443	73	72	17	67	18
	22	66	NW	2	1	0	93	359	71	69.7	13	63	4
	23	63.5	NE	2	1	0	87	835	69	68.7	13	63	8
	24	68	E	2	1	0	87	813	73	71.5	14	62.5	10
	25	68	S	2	1	0	90	516	68	67	10	63	12
	26	70	N	5	1	0	72	1590	69	68	10	65	17
	27	59.5	NE	3	1	0	82	939	65	63.5	12	57	6
	28	62	E	3	3	0	94	338	64.8	64	12	59	10
	29	59	N	5	3	63	84	838	64	64	b	63	11
	30	59	NE	4	1	0	82	604	69.5	67	a	54	6
Total						108					358		332
Mean		70.5							71.5	70.7	12.8	66.9	11.1

a — no reading made. b — observation discarded.

October.

River Pan.											Land Pan.	
Date.	Mean Temperature.	Wind. Direction.	Wind. Velocity.	State of Weather.	Precipitation.	Relative Humidity.	Saturation Deficit.	Temperature of Water. Outside.	Temperature of Water. Inside.	Evaporation.	Temperature of Water.	Evaporation.
1	54.5	N	1	1	0	90	321	59	58	24	54	6
2	54.5	NW	1	1	0	96	186	59	58.5	12	54	10
3	59.5	a	a	1	0	98	50	59	59	12	54	6
4	61.5	SE	1	3	4	89	740	62	61.7	3	63	2
5	65.5	a	a	3	0	a	a	a	a	a	a	a
6	48	NW	2	1	0	98	24	58	56.8	17	51	20
7	50.5	NW	1	1	0	94	167	57	56	10	52	8
8	63	SW	2	1	0	75	1404	58	58	9	55	9
9	55.5	NW	5	2	0	86	333	52.2	51	b	48	15
10	36	NW	2	1	0	93	116	49	47.8	b	44	12
11	32	S	2	3	0	92	179	45.4	44	b	40	8
12	40.5	SE	2	1	0	86	602	43.5	43	8	42	8
13	55	SE	3	1	0	81	1062	48.7	48	8	49	6
14	63.5	E	2	1	0	78	1052	53	52	13	52	3
15	62	NE	2	3	0	77	1220	54.8	54.4	13	53	10
16	60.5	E	2	1	0	80	779	56.3	55.8	10	53	6
17	64	NE	1	1	0	85	566	a	a	b	b	b
18	60.5	SE	1	3	10	95	186	58	57.8	4	57	2
19	50	SE	1	1	3	91	352	55.6	54	19	50	3
20	54	SE	2	1	0	78	1144	a	a	10	a	a
21	59	E	3	2	0	83	717	55.6	55	10	52	6
22	61	NE	2	3	0	93	257	56	55	9	52	7
23	58	NE	4	3	0	94	166	55	54	10	51	8
24	45.5	SW	3	2	0	92	218	b	b	b	50	6
25	41	S	2	1	5	91	328	51.5	50	3	47	5
26	49.5	SE	2	2	0	94	213	b	b	b	b	5
27	48.5	NW	6	3	40	88	276	50	b	b	47	2
28	37.5	NW	4	3	0	80	369	47	46	b	42	7
29	40	S	3	3	0	88	352	46.5	45	8	45	8
30	44.5	N	2	3	0	89	216	44.6	44	8	43	7
31	30.5	E	1	1	0	87	234	43	42	6	37	4
Total					62					226		199
Mean	51.8							52.9	52.3	9.82	49.5	6.42

a — no reading made. b — observation discarded.

November.

	River Pan.											Land Pan.	
Date.	Mean Temperature.	Wind. Direction.	Wind. Velocity.	State of Weather.	Precipitation.	Relative Humidity.	Saturation Deficit.	Temperature of Water. Outside.	Temperature of Water. Inside.	Evaporation.		Temperature of Water.	Evaporation.
1		SE	2	—	0	88	291	41.6	39	4		37	2
2	34	SE	2	1	0	88	291	41.5	38.5	6		35	5
3	40.5	—	—	2	0	—	—	—	—	2		—	2
4	41.5	—	—	3	0	91	296	41.5	41	4		42	6
5	48	SE	2	2	0	87	464	41.5	41	3		42	3
6	48.5	SE	2	1	0	85	746	45	46	4		47	2
7	49.5	SE	1	2	0	91	319	46	46	1		47	3
8	59	N	1	3	15	96	138	48	46.5	0		48	1
9	44	NW	4	3	0	88	278	48	47	2		45	2
10	45.5	S	2	1	0	98	40	47	46	8		43	4
11	40	NW	3	3	11	94	96	45.4	43.8	7		38	5
12	36.5	N	3	1	Tr.	88	197	42	39	5		37	2
13	30	—	0	1	0	93	110	40	36.5	2		34	2
14	26	SE	1	1	0	93	108	38	37	2		35	2
15	26.5	—	—	2	0	96	151	37	34.5	2		34	0
16	33	SE	5	3	0	94	146	36.5	34	2		34	4
17	36	W	2	3	12	93	111	38	38	2		41	4
18	41.5	W	3	1	0	95	47	32	34	8		34	—
19	30.5	NW	3	1	0	93	84	37	33.2	a		33	—
20	—	—	—	—	—	—	—	—	—	—		—	—
Total					38					64			49
Mean	39.5							41.4	40.1	3.56		39.2	3.06

February, 1907.